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Canadian Science Advisory Secretariat (CSAS)

Research Document 2013/002

Quebec Region

Update of the estimation of northern shrimp *Pandalus borealis* biomass and abundance from the trawl survey in the Estuary and the northern Gulf of St. Lawrence in 2012

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May 2013

Canada

Foreword

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Published by:

Fisheries and Oceans Canada
Canadian Science Advisory Secretariat
200 Kent Street
Ottawa ON K1A 0E6

http://www.dfo-mpo.gc.ca/csas-sccs/
csas-sccs@dfo-mpo.gc.ca

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ISSN 1919-5044

Correct citation for this publication:

Savard, L. and Bourdages H. 2013. Update of the estimation of northern shrimp *Pandalus borealis* biomass and abundance from the trawl survey in the Estuary and the northern Gulf of St. Lawrence in 2012. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/002. iv + 30 p.

Aussi disponible en français :

Savard, L. et Bourdages H. 2013. Mise à jour de l'estimation de biomasse et d'abondance de la crevette nordique Pandalus borealis à partir du relevé de chalutage dans l'estuaire et le nord du golfe du Saint-Laurent en 2012. Secr. can. de consult. sci. du MPO. Doc. de rech. 2013/002. iv + 30 p.

ABSTRACT

The Estuary and Gulf of St. Lawrence northern shrimp (*Pandalus borealis*) stock status is determined every year by examining a main indicator from the commercial fishery and the research survey. This document presents the data and methods that are used to produce the 2012 survey indicators. The estimates of northern shrimp biomass and abundance are presented for each of the four fishing areas and for each sex.

SOMMAIRE

L'état des stocks de crevette nordique (*Pandalus borealis*) de l'estuaire et du golfe du Saint-Laurent est déterminé chaque année par l'examen d'un indicateur principal provenant de la pêche commerciale et du relevé de recherche. Ce document présente les données et méthodes utilisées pour produire les indicateurs du relevé de 2012. Les estimations de biomasse et d'abondance de la crevette nordique sont présentées pour chacune des quatre zones de pêche et pour chacun des sexes.

INTRODUCTION

The northern shrimp (*Pandalus borealis*) fishery is conducted by trawlers in four shrimp fishing areas (SFA): Estuary (SFA 12), Sept-Iles (SFA 10), Anticosti (SFA 9) and Esquiman (SFA 8) (Figure 1). Fishing is regulated by several management measures, including the setting of total allowable catches (TAC) for each of the four areas. The TAC is set each year from the main stock status indicator. The main indicator of stock status is calculated from the male (recruitment to the female component) and female indices (spawning stock) obtained from the summer fishery (number per unit effort) and research survey (abundance) (DFO 2012, Savard 2012).

This document updates the data and methods that are used to produce the survey indicators and that were described in Savard and Bourdages 2012. The estimates of biomass and of abundance are presented for each of the four fishing areas and for each sex. The weight-length relationships are also presented as well as the length frequency distributions that are used for the age group identification.

DESCRIPTION OF THE SURVEY

A research survey has been conducted in the Estuary and the northern Gulf of St. Lawrence since 1990 to estimate the abundance of northern shrimp and of some groundfish species. The survey is conducted with a shrimp trawl following a stratified random sampling plan. Fishing operations take place 24 hours a day. A description of the 2012 survey fishing and sampling protocols is presented in Archambault *et al.* 2013.

The stratification used for the allocation of fishing stations is presented in figure 2. In the Gulf, the grounds located at depths greater than 37 m (20 fathoms) are covered by the survey. In the Estuary, the survey covered the grounds at depths greater than 183 m (100 fathoms) from 1990 to 2007. In 2008, it was decided to add strata to cover depths from 37 to 183 m to obtain a better coverage of the northern shrimp spatial distribution.

PROCESSING OF SHRIMP CATCHES

For each fishing tow, the trawl catch is sorted by species or by taxon. The total catch of shrimp is weighted and a sample of about 2 kg is collected to determine the proportion of *Pandalus borealis* and its biological characteristics as well. The maturity stage (male, primiparous or mutiparous female with or without gonads in maturation and egg bearing female) is identified for each individual. The cephalothorax length is measured with an electronic calliper with a precision of 0.1 mm. The individual weight is recorded with a precision of 0.1 g following a stratified sampling design (about ten individuals per sex per 1 mm length class) for each fishing area.

The area swept by the trawl is estimated from the duration of the tow, the speed of the vessel and the horizontal opening of the trawl. The *P. borealis* catch for each tow is estimated from its proportion in the sample and is standardized to an area of 1 km² by dividing it by the swept area.

DISTRIBUTION AND MEAN CATCH OF NORTHERN SHRIMP

The survey is considered to cover well the whole *Pandalus borealis* distribution in the Estuary and the northern Gulf of St. Lawrence (Figure 3). Northern shrimp is generally restricted to grounds located under the cold intermediate layer at depths greater than 150 m. In 2010, problems with the winches combined to many major tears-up of the trawl prevented the sampling of stations located in the southern part of 4R (strata 802, 810, 820 and 835) and in the eastern part of Laurentian Channel (strata 401, 404 and 407). On average, 200 fishing stations are sampled by year (Table 1).

The box plot of the catches for the last three years is presented in figure 4. The mean catches are also presented by fishing area and by year, for males and females (Table 2).

BIOMASS ESTIMATION BY KRIGING

The catch in kg/km² calculated at all stations of the study area is kriged separately for males and females. In 2010, the absence of data in the south east sector of the study area (Figure 3) could have produced an overestimation of the biomass given that this sector sustains habitually low northern shrimp concentrations. This bias was avoided by completing the 2010 missing strata with the data collected in the same sector in 2009.

As a first step, a variogram is calculated for each survey with the VARIO procedure of the SAS software (SAS 1996). The catch extreme values (see table in the text for the last three years) are removed from the analysis so as to highlight the spatial structure of the data. The extreme values are reintegrated thereafter for the kriging.

Catch values above which the data were removed from the variogram estimation.

	2010	2011	2012
Males	7 000	3 000	8 000
Females	-	5 000	3 500

The kriging that is performed each year to evaluate the biomass is based on a pluriannual variogram which is built from the standardized variograms (i.e. each variogram is divided by variance of the survey catch) of the current year and of the two preceding years. The pluriannual variogram corresponds to the mean of the semi-variances for each distance *h* of the annual variograms, weighted by the number of pairs for the same distances. A model is manually fitted to the pluriannual variogram to allow the estimation of the different parameters (the nugget, sill and range) (Figure 5 and Table 3). Although other types of model were examined when it seemed appropriated to do so, the exponential model was chosen because it was felt that it gave the best fit (Figure 5). The use of a pluriannual variogram decreases the variability of the spatial structure that is observed for some years and allows a better fit of the model. Finally, the pluriannual variograms are multiplied by the variance of the data to be kriged.

The kriging mean and the variance of the estimate are estimated with the MATLAB «Kriging» toolbox (Lafleur and Gratton, 1998). For each year, point estimates are obtained at each node of a grid of 4,501 5 by 5 km meshes that covers the entire studied area (112,525 km²). The addition in 2008 of new strata in the Estuary increased the grid to 4,598 meshes for a total area of 114,950 km² (Figure 6). These point estimates are obtained by using the eight stations that are the closest in a maximum search radius of 200 km.

The mean biomass (kg/km²) of each fishing area is then calculated by doing the mean of the point estimates of the area. The total biomass of a given fishing area is obtained by multiplying the mean biomass by the surface of the area. The surfaces of the fishing areas are as followed: Estuary, 4,000 km² from 1990 to 2007 and 6,325 km² from 2008 to 2010; Sept-Iles, 29,775 km² from 1990 to 2007 and 29,975 km² from 2008 to 2010; Anticosti, 46,400 km²; Esquiman, 32,350 km².

The mean biomass and the variance of the estimation are presented for males and females and, for each fishing area, in tables 4 and 5. In general, the coefficient of variation is about 20 to 25% for males and 10 to 18% for females for the fishing areas Sept-Iles, Anticosti and Esquiman (Table 6). The coefficient of variation id higher in the Estuary area. The distribution of the mean biomass per mesh of 25 km² is presented by year, for males and females, in figure 7. The total biomass for each fishing area, for males and females, is presented in table 7 and figure 8.

ABUNDANCE ESTIMATION

Biomasses estimated by kriging are converted into abundance from the weight-length relationships and from the length frequency distributions. Length frequencies of each sample are first bumped to the total catch of the station and then, standardized to a 1 km² swept area. The frequencies (n/km²) are regrouped into 0.5 mm size class.

The mean distribution of frequencies (in n/km²) per size class is estimated for each fishing area, for males and females. The mean distribution is estimated from all stations that were sampled in the fishing area. The mean distribution is then converted into weight by applying a weight-length relationship that is estimated for each area (Table 8, Figure 9). The weight-length relationship estimated in 1993 is used for the 1990-2004 period. Since 2005, the relationship estimated annually is used for the current year. The same relationship is used for both sexes.

The stock biomass estimated by kriging is distributed among the size classes following the proportions in weight of the mean distribution of the stock. The abundance of each size class is obtained by dividing the biomass by the mean weight of the class. The total stock abundance is then obtained by adding the abundance of all size classes. The exercise is done separately for males and females. Given that the numbers are not kriged, it is not possible to obtain an estimate of the variance of the abundance by kriging. Therefore, the coefficient of variation of the biomass is used to estimate the confidence interval of the abundance.

The total abundance of each fishing area is presented separately for males and females in table 9 and in figure 10. The abundance distributions by size class are presented for each fishing area in figure 11.

It is possible to obtain an index of recruitment by estimating the abundance of juveniles for which the cephalothorax length is smaller than 12 or 13 mm. The individuals of these sizes are aged of about fifteen months (Daoud *et al.* 2010). The estimation of abundance of the juveniles is obtained by adding the abundance of the size classes that are included in the first mode (Table 10).

The female abundance could be separated into maturity stages for the years when the identification of the stage was done for each individual. The abundance of primiparous and multiparous females was calculated from 1990 to 2000 and then from 2009 to 2012 and is

presented in table 10. Carapace length frequencies by maturity stage from 2009 to 2012 are presented in figure 12.

ACKNOWLEDGEMENTS

Sincere thanks to the numerous biologists and technicians who have collected the survey data.

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Table 1. Mean catch (kg/km²) and standard error by year, for males and females for the whole studied area (n: number of stations).

Year	n	Males		Females	
		mean	standard error	mean	standard error
1990	219	352.82	55.45	485.40	52.97
1991	250	265.82	50.53	412.06	50.09
1992	239	155.80	26.40	243.80	29.20
1993	214	203.54	32.87	184.91	22.54
1994	176	201.98	33.29	302.51	38.02
1995	182	339.35	47.62	408.27	44.58
1996	217	439.20	61.95	680.02	57.96
1997	185	602.88	92.43	715.33	82.08
1998	206	352.73	40.84	723.22	73.51
1999	224	472.81	64.43	659.18	62.95
2000	209	527.95	64.46	971.07	82.90
2001	183	572.65	100.29	632.05	67.32
2002	171	470.10	88.08	797.77	88.42
2003	164	1429.82	303.30	1339.45	135.14
2004	133	726.32	136.25	1178.16	144.69
2005	354	536.26	72.52	931.23	68.48
2006	192	477.52	73.83	942.93	111.75
2007	183	610.36	101.27	1141.70	158.19
2008	189	489.41	84.41	762.88	82.68
2009	164	586.99	89.54	686.89	78.53
2010	154	484.46	70.62	750.56	88.77
2011	156	357.29	54.43	637.68	74.19
2012	178	506.20	114.22	533.69	75.38
2008+	201	488.33	80.51	842.41	90.62
2009+	177	594.41	83.94	758.17	83.23
2010+	166	518.46	79.87	778.55	89.04
2011+	166	408.65	59.41	669.28	77.29
2012+	188	517.62	109.33	550.84	74.19

+: From 2008, the sampling was increased with the addition of strata in shallow waters (37 to 183 m) in the Estuary.

Table 2a. Mean catch (kg/km²) and standard error by year, for males and females for the Estuary fishing area (n: number of stations).

Year	n	Males		Females	
		mean	standard error	mean	standard error
1990	12	156.25	77.64	233.60	82.83
1991	11	31.24	15.16	308.55	140.68
1992	11	83.57	64.96	187.46	120.91
1993	12	102.41	77.18	229.46	142.70
1994	8	119.96	83.70	398.96	271.60
1995	18	33.17	15.68	44.56	18.74
1996	17	134.78	53.69	663.29	244.99
1997	16	31.89	13.05	146.69	94.02
1998	16	34.26	18.48	161.65	64.16
1999	21	124.26	90.38	595.85	201.84
2000	17	54.91	20.71	440.13	129.52
2001	19	13.16	3.83	271.45	99.19
2002	12	10.35	6.37	125.35	81.23
2003	11	29.98	12.64	346.45	251.45
2004	9	140.30	109.56	722.40	367.20
2005	24	35.06	17.05	466.44	138.59
2006	12	5.88	2.02	208.67	76.78
2007	12	18.40	14.15	144.46	62.58
2008	10	17.17	6.47	379.22	159.30
2009	10	43.48	24.17	405.83	193.35
2010	12	77.14	42.62	240.65	137.06
2011	12	200.34	89.92	459.60	168.05
2012	11	168.99	104.59	541.11	296.08
2008+	21	276.87	141.96	1377.69	446.43
2009+	23	407.81	121.58	1113.27	320.01
2010+	24	515.91	328.56	689.18	259.32
2011+	22	659.22	231.83	779.03	272.70
2012+	20	439.16	174.32	715.69	248.12

+: From 2008, the sampling was increased with the addition of strata in shallow waters (37 to 183 m) in the Estuary.

Table 2b. Mean catch (kg/km²) and standard error by year, for males and females for the Sept-Iles fishing area (n: number of stations).

Year	n	Males		Females	
		mean	standard error	mean	standard error
1990	73	363.67	92.77	645.86	97.51
1991	71	556.18	162.63	828.79	150.54
1992	60	205.76	56.56	366.16	78.76
1993	47	376.55	94.09	378.55	73.66
1994	49	360.66	97.71	605.39	103.66
1995	56	466.30	96.10	576.97	95.30
1996	74	580.36	108.36	998.30	93.68
1997	53	827.38	159.76	1096.29	125.72
1998	48	533.44	86.71	1478.68	219.66
1999	62	715.13	119.52	989.24	102.19
2000	51	1010.98	164.56	1854.22	159.49
2001	58	1148.10	272.58	1132.47	155.61
2002	56	871.06	228.82	1693.26	194.25
2003	48	3127.80	919.28	2586.05	228.81
2004	43	1248.80	289.40	2115.43	274.37
2005	65	1216.62	286.97	1908.19	135.10
2006	50	655.40	157.80	1879.13	259.20
2007	50	1063.61	313.79	2293.81	339.12
2008	44	1015.39	288.15	2035.72	203.67
2009	44	823.44	240.35	1186.55	194.23
2010	40	644.78	150.85	1410.74	191.62
2011	40	416.79	86.93	1003.56	145.39
2012	42	1156.22	382.08	936.71	113.12
2008+	45	993.13	282.55	1990.48	204.17
2009+	44	823.44	240.35	1186.55	194.23
2010+	40	644.78	150.85	1410.74	191.62
2011+	40	416.79	86.93	1003.56	145.39
2012+	43	1135.94	373.64	919.54	111.78

+: From 2008, the sampling was increased with the addition of strata in shallow waters (37 to 183 m) in the Estuary.

Table 2c. Mean catch (kg/km²) and standard error by year, for males and females for the Anticosti fishing area (n: number of stations).

Year	n	Males		Females	
		mean	standard error	mean	standard error
1990	85	432.32	110.06	403.26	90.79
1991	82	185.47	37.18	257.11	41.09
1992	82	211.64	59.86	232.17	43.47
1993	76	207.97	64.32	141.47	25.94
1994	64	161.66	36.65	184.98	33.22
1995	57	378.62	87.89	470.25	71.13
1996	63	494.89	135.38	729.94	125.45
1997	60	489.25	105.34	608.31	86.48
1998	78	338.21	56.43	608.31	76.83
1999	78	381.33	67.30	566.40	68.19
2000	77	394.02	73.62	850.59	104.52
2001	36	203.40	60.44	373.80	59.72
2002	49	473.86	119.72	630.52	110.73
2003	46	802.31	297.96	852.31	205.04
2004	32	603.76	293.42	754.94	231.18
2005	134	515.14	96.84	972.32	112.61
2006	64	390.95	113.07	665.84	135.96
2007	66	581.38	106.72	1072.25	308.50
2008	66	287.91	59.27	392.17	72.02
2009	60	560.52	125.19	496.11	91.53
2010	54	522.58	122.00	564.83	114.99
2011	52	202.73	59.32	338.22	84.78
2012	59	190.56	45.90	338.12	62.70

Table 2d. Mean catch (kg/km²) and standard error by year, for males and females for the Esquiman fishing area (n: number of stations).

Year	n	Males		Females	
		mean	standard error	mean	standard error
1990	49	246.89	73.44	450.49	94.34
1991	86	132.72	36.35	229.00	41.98
1992	86	76.95	20.47	176.71	38.87
1993	79	111.72	23.93	104.71	20.02
1994	55	119.45	37.17	155.41	36.81
1995	51	264.14	85.30	282.14	79.76
1996	63	299.84	100.71	260.78	58.81
1997	56	675.28	236.46	631.90	215.63
1998	64	314.52	87.65	437.06	104.71
1999	63	463.79	172.20	470.35	162.91
2000	64	429.80	124.02	553.29	164.08
2001	70	437.61	105.14	448.10	92.41
2002	54	153.06	68.92	170.30	54.02
2003	59	798.65	221.03	890.21	221.46
2004	49	455.49	171.87	715.75	219.21
2005	131	312.10	78.31	489.59	102.93
2006	66	512.47	138.68	635.89	191.06
2007	55	362.24	106.21	395.24	106.46
2008	69	415.18	116.38	361.42	100.03
2009	50	519.38	133.70	532.32	135.96
2010	48	409.82	126.00	536.82	167.73
2011	52	502.30	132.68	696.79	158.63
2012	66	430.92	171.37	450.83	170.26

Table 3a. Parameters of the variograms used for kriging the male biomass. An exponential model was used each year.*

Year	Period	Parameters		
		Nugget (c_0)	Sill ($c_0 + c$)	Range (a_0)
1990	1990-1991-1992	0.50	1.05	35
1991	1990-1991-1992	0.50	1.05	35
1992	1990-1991-1992	0.50	1.05	35
1993	1991-1992-1993	0.20	1.05	30
1994	1992-1993-1994	0.20	1.05	30
1995	1993-1994-1995	0.20	1.00	20
1996	1994-1995-1996	0.20	1.00	20
1997	1995-1996-1997	0.20	0.95	18
1998	1996-1997-1998	0.20	0.90	20
1999	1997-1998-1999	0.40	0.90	20
2000	1998-1999-2000	0.40	0.90	20
2001	1999-2000-2001	0.40	0.90	17
2002	2000-2001-2002	0.30	1.00	25
2003	2001-2002-2003	0.20	1.00	25
2004	2002-2003-2004	0.20	1.00	25
2005	2003-2004-2005	0.30	1.00	30
2006	2004-2005-2006	0.30	1.00	25
2007	2005-2006-2007	0.30	1.00	25
2008	2006-2007-2008	0.30	1.00	20
2009	2007-2008-2009	0.25	1.00	25
2010	2008-2009-2010	0.30	1.00	25
2011	2009-2010-2011	0.40	1.00	30
2012	2010-2011-2012	0.30	1.00	22

* Exponential model : (where h = distance) $\gamma(h) = c_0 + c\left[1 - \exp\left(-\frac{h}{a_0}\right)\right]$

Table 3b. Parameters of the variograms used for kriging the female biomass. An exponential model was used each year.*

Year	Period	Parameters		
		Nugget (c_0)	Sill ($c_0 + c$)	Range (a_0)
1990	1990-1991-1992	0.45	0.95	30
1991	1990-1991-1992	0.45	0.95	30
1992	1990-1991-1992	0.45	0.95	30
1993	1991-1992-1993	0.25	0.85	20
1994	1992-1993-1994	0.30	0.85	25
1995	1993-1994-1995	0.30	0.80	20
1996	1994-1995-1996	0.15	0.95	17
1997	1995-1996-1997	0.15	0.95	17
1998	1996-1997-1998	0.20	0.95	20
1999	1997-1998-1999	0.35	0.90	25
2000	1998-1999-2000	0.35	0.90	30
2001	1999-2000-2001	0.40	0.90	35
2002	2000-2001-2002	0.30	0.90	30
2003	2001-2002-2003	0.20	0.85	35
2004	2002-2003-2004	0.15	0.95	35
2005	2003-2004-2005	0.20	1.05	60
2006	2004-2005-2006	0.20	1.05	50
2007	2005-2006-2007	0.20	1.05	60
2008	2006-2007-2008	0.20	1.00	60
2009	2007-2008-2009	0.20	0.90	40
2010	2008-2009-2010	0.25	0.90	45
2011	2009-2010-2011	0.15	0.90	28
2012	2010-2011-2012	0.15	0.90	27

* Exponential model : (where h = distance) $\gamma(h) = c_0 + c\left[1 - \exp\left(-\frac{h}{a_0}\right)\right]$

Table 4. Mean biomass (kg/km²) estimated by kriging, by fishing area and by year, for males (M) and females (F).

Year	Estuary		Sept-Iles		Anticosti		Esquiman	
	M	F	M	F	M	F	M	F
1990	188.6	310.3	388.1	648.6	416.8	417.3	234.2	402.2
1991	44.3	514.4	566.7	774.9	207.0	300.7	186.0	287.1
1992	100.1	365.1	219.6	358.7	264.7	277.0	92.4	202.5
1993	88.9	274.6	336.3	442.0	207.7	150.1	114.3	107.1
1994	102.7	426.0	376.1	598.4	165.3	179.5	175.6	196.0
1995	33.1	52.9	426.2	559.8	392.7	509.3	334.5	327.7
1996	116.6	598.7	467.0	880.3	659.8	931.3	329.5	299.2
1997	69.7	375.4	777.2	999.6	456.7	552.9	747.2	693.7
1998	24.1	144.2	550.5	1541.5	269.5	566.0	366.8	481.2
1999	136.2	575.1	788.0	1098.1	345.9	551.8	455.2	457.9
2000	141.1	702.4	1005.3	1777.0	403.7	832.1	439.2	536.8
2001	22.2	439.9	1273.0	1141.9	331.2	508.2	452.4	452.9
2002	22.0	312.8	980.1	1713.5	594.6	739.4	197.3	217.7
2003	105.8	691.4	2952.5	2767.2	966.2	1232.6	873.0	998.9
2004	92.5	626.7	1444.4	2312.6	564.3	905.7	434.7	768.0
2005	44.6	554.1	925.5	1978.5	655.3	1141.9	596.3	853.5
2006	45.8	419.7	631.4	1873.1	385.9	685.7	713.6	847.1
2007	221.3	592.0	945.0	2364.0	623.5	1223.3	517.6	462.8
2008	23.6	617.7	835.7	2112.6	361.6	481.1	492.8	426.4
2009	49.0	356.0	1031.0	1336.2	593.7	532.2	547.0	536.9
2010	98.7	341.0	715.6	1527.8	534.5	570.9	447.7	568.0
2011	185.9	496.6	488.8	1024.8	218.0	432.3	624.7	831.8
2012	160.6	658.4	1223.6	1015.0	268.4	473.3	452.8	507.8
2008+	284.6	1405.3	833.4	2103.8				
2009+	421.3	1157.2	1028.8	1334.6				
2010+	540.0	709.0	714.2	1526.1				
2011+	557.9	588.7	490.2	1014.4				
2012+	490.8	779.5	1220.6	1007.8				

+: From 2008, the sampling was increased with the addition of strata in shallow waters (37 to 183 m) in the Estuary.

Table 5. Variance of the estimation of the kriged biomass, by fishing area and by year, for males (M) and females (F).

Year	Estuary		Sept-Iles		Anticosti		Esquiman	
	M	F	M	F	M	F	M	F
1990	4017.6	4274.8	7021.6	7304.2	10192.9	6534.1	4823.3	7464.5
1991	175.0	14135.8	20184.6	16312.5	1142.5	1318.1	1025.2	1290.6
1992	2889.1	9386.4	2418.6	4421.5	3123.9	1551.7	287.8	973.7
1993	3257.9	11854.8	5001.6	3237.9	3044.1	496.2	341.8	252.3
1994	4333.3	44881.7	6559.9	7047.7	1063.4	809.0	981.7	920.5
1995	138.2	184.9	6052.7	5309.6	6545.1	3565.1	7931.6	5447.8
1996	1661.4	34512.2	9582.1	7200.8	18014.2	15678.5	7533.5	2602.9
1997	89.3	4533.2	20035.0	12572.2	13816.4	9611.2	44832.4	37827.8
1998	175.7	2211.0	4955.2	33380.5	2844.0	5563.0	4727.3	7071.3
1999	5460.0	24194.3	12434.5	8356.2	3802.9	3592.7	22794.7	18562.5
2000	261.1	8587.2	20684.7	16765.5	4595.1	8055.2	10630.5	15817.3
2001	9.9	5402.3	57882.0	15298.4	6710.7	5975.8	8391.6	5206.7
2002	24.8	3479.1	34710.1	21593.7	13689.0	9947.7	3730.6	1933.0
2003	137.6	40316.7	692470.1	31793.1	78968.9	27469.3	40240.9	29395.7
2004	7318.7	62394.7	70330.5	48562.7	104139.5	58084.9	20952.9	26519.8
2005	180.4	7732.5	80284.8	12192.0	10317.2	9624.7	5513.5	6327.3
2006	2.5	2363.9	15240.4	27257.6	13359.6	14831.0	14120.9	17881.4
2007	182.6	2429.3	69055.2	50189.7	8115.5	42275.1	8995.3	5695.8
2008	34.1	11876.5	71664.7	20796.5	3074.2	2489.1	11688.6	4767.0
2009	359.4	16269.4	43339.6	19944.3	15917.5	6212.3	13694.5	9953.4
2010	1199.9	8550.3	17090.1	18802.6	12686.3	7719.6	11125.1	13507.2
2011	5292.7	13730.9	6159.3	14603.1	2754.1	4689.5	13370.5	15675.7
2012	8591.4	52747.3	109474.1	7221.6	2386.2	3737.0	23884.9	18109.7
2008+	16837.4	96219.7	70057.4	21174.5				
2009+	7551.8	36900.7	43280.0	19909.2				
2010+	64915.2	28040.2	17019.7	18753.7				
2011+	36104.9	37810.2	6174.8	14658.9				
2012+	20938.8	32736.8	98727.4	6942.2				

+: From 2008, the sampling was increased with the addition of strata in shallow waters (37 to 183 m) in the Estuary.

Table 6. Coefficient of variation of the kriged biomass, by fishing area and by year, for males (M) and females (F).

Year	Estuary		Sept-Iles		Anticosti		Esquiman	
	M	F	M	F	M	F	M	F
1990	33.6	21.1	21.6	13.2	24.2	19.4	29.7	21.5
1991	29.9	23.1	25.1	16.5	16.3	12.1	17.2	12.5
1992	53.7	26.5	22.4	18.5	21.1	14.2	18.4	15.4
1993	64.2	39.6	21.0	12.9	26.6	14.8	16.2	14.8
1994	64.1	49.7	21.5	14.0	19.7	15.8	17.8	15.5
1995	35.5	25.7	18.3	13.0	20.6	11.7	26.6	22.5
1996	35.0	31.0	21.0	9.6	20.3	13.4	26.3	17.0
1997	13.5	17.9	18.2	11.2	25.7	17.7	28.3	28.0
1998	54.9	32.6	12.8	11.9	19.8	13.2	18.7	17.5
1999	54.3	27.0	14.2	8.3	17.8	10.9	33.2	29.8
2000	11.5	13.2	14.3	7.3	16.8	10.8	23.5	23.4
2001	14.1	16.7	18.9	10.8	24.7	15.2	20.2	15.9
2002	22.7	18.9	19.0	8.6	19.7	13.5	31.0	20.2
2003	11.1	29.0	28.2	6.4	29.1	13.4	23.0	17.2
2004	92.5	39.9	18.4	9.5	57.2	26.6	33.3	21.2
2005	30.1	15.9	30.6	5.6	15.5	8.6	12.5	9.3
2006	3.4	11.6	19.6	8.8	30.0	17.8	16.7	15.8
2007	6.1	8.3	27.8	9.5	14.4	16.8	18.3	16.3
2008	24.7	17.6	32.0	6.8	15.3	10.4	21.9	16.2
2009	38.7	35.8	20.2	10.6	21.2	14.8	21.4	18.6
2010	35.1	27.1	18.3	9.0	21.1	15.4	23.6	20.5
2011	39.1	23.6	16.1	11.8	24.1	15.8	18.5	15.1
2012	57.7	34.9	27.0	8.4	18.2	12.9	34.1	26.5
2008+	45.6	22.1	31.8	6.9				
2009+	20.6	16.6	20.2	10.6				
2010+	47.2	23.6	18.3	9.0				
2011+	34.1	33.0	16.0	11.9				
2012+	29.5	23.2	25.7	8.3				

+: From 2008, the sampling was increased with the addition of strata in shallow waters (37 to 183 m) in the Estuary.

Table 7. Stock biomass (ton) estimated by kriging by fishing area and by year, for males (M) and females (F).

Year	Estuary		Sept-Iles		Anticosti		Esquiman	
	M	F	M	F	M	F	M	F
1990	754	1241	11557	19312	19340	19361	7576	13011
1991	177	2057	16874	23073	9604	13951	6018	9287
1992	401	1460	6538	10682	12284	12851	2989	6551
1993	356	1099	10012	13161	9636	6963	3698	3466
1994	411	1704	11198	17817	7670	8331	5681	6339
1995	132	212	12689	16667	18222	23630	10822	10601
1996	466	2395	13906	26212	30616	43214	10658	9680
1997	279	1501	23140	29763	21192	25652	24171	22442
1998	97	577	16390	45898	12503	26264	11866	15566
1999	545	2301	23463	32695	16051	25605	14724	14812
2000	564	2809	29933	52910	18732	38609	14207	17364
2001	89	1760	37904	34000	15367	23582	14635	14650
2002	88	1251	29183	51020	27590	34308	6382	7043
2003	423	2766	87910	82393	44832	57191	28242	32313
2004	370	2507	43008	68857	26183	42025	14062	24845
2005	178	2217	27558	58911	30406	52984	19291	27612
2006	183	1679	18801	55773	17905	31818	23086	27404
2007	885	2368	28137	70389	28931	56762	16744	14971
2008	95	2471	24882	62904	16780	22322	15944	13795
2009	196	1424	30697	39785	27549	24693	17696	17369
2010	395	1364	21308	45491	24801	26488	14483	18374
2011	743	1986	14555	30512	10114	20059	20209	26907
2012	643	2634	36433	30222	12455	21962	14648	16426
2008+	1800	8889	24898	62852				
2009+	2665	7319	30734	39872				
2010+	3415	4484	21338	45592				
2011+	3528	3724	14644	30306				
2012+	3104	4930	36466	30109				

+: From 2008, the sampling was increased with the addition of strata in shallow waters (37 to 183 m) in the Estuary.

Table 8. Parameters for the weight-length relationships by fishing area and by year. Length in mm and weight in g.*

Year	Estuary		Sept-Iles		Anticosti		Esquiman	
	a	b	a	b	a	b	a	b
1990								
1991								
1992								
1993	2.945	0.00071	2.978	0.00066	3.018	0.00059	2.864	0.00094
1994								
1995								
1996								
1997								
1998								
1999								
2000								
2001								
2002								
2003								
2004								
2005	2.777	0.00117	2.960	0.00065	2.957	0.00066	2.904	0.00075
2006	2.945	0.00068	2.934	0.00069	3.040	0.00053	2.849	0.00093
2007	2.800	0.00107	2.930	0.00072	2.918	0.00074	2.904	0.00077
2008	3.016	0.00056	2.934	0.00070	2.908	0.00077	2.887	0.00082
2009	2.977	0.00063	2.864	0.00090	2.893	0.00080	2.911	0.00077
2010	2.920	0.00076	2.931	0.00072	3.011	0.00059	2.953	0.00071
2011	2.911	0.00076	2.942	0.00068	3.001	0.00062	3.034	0.00055
2012	2.9307	0.00073	2.9359	0.00073	2.9231	0.00077	2.9082	0.00081

* Model : Weight = a Length ^{b}

Table 9. Stock abundance (in million) by fishing area and by year, for males (M) and females (F).

Year	Estuary		Sept-Iles		Anticosti		Esquiman	
	M	F	M	F	M	F	M	F
1990	156	115	2258	1813	4849	2145	1661	1394
1991	26	196	3871	2278	1948	1459	1214	978
1992	87	128	2111	960	2926	1251	630	660
1993	85	92	2892	1263	2646	671	866	358
1994	87	163	3289	1917	1886	919	1470	716
1995	40	20	2917	1706	4850	2680	2679	1366
1996	86	225	3016	2665	7382	4766	3194	1206
1997	48	132	4936	2828	5848	2602	6490	2790
1998	25	49	3439	4194	2603	2561	3097	1807
1999	118	204	5792	3110	3907	2558	4109	1845
2000	114	256	6526	5326	4953	4006	4015	2135
2001	18	162	8550	3501	3601	2423	4606	1922
2002	20	125	6656	5541	7989	3896	1739	907
2003	219	270	17554	8981	12619	6736	8043	4298
2004	62	238	8513	7711	7066	5149	3738	3419
2005	29	222	6277	6496	6315	6438	4880	3912
2006	28	164	3804	6132	4319	3781	7161	3667
2007	141	226	6167	7247	8122	7219	5885	2241
2008	19	222	5619	6531	4793	2835	4937	2198
2009	43	133	7931	4309	9963	3257	5369	2527
2010	79	129	5937	5270	6475	3251	3632	2468
2011	178	231	3749	3637	2627	2420	5911	3401
2012	130	305	8341	3631	2957	2557	4307	2081
2008+	456	830	5623	6525				
2009+	1252	732	7941	4319				
2010+	1072	467	5945	5282				
2011+	1069	433	3772	3613				
2012+	821	585	8350	3617				

+: From 2008, the sampling was increased with the addition of strata in shallow waters (37 to 183 m) in the Estuary.

Table 10. Abundance (in million) for juveniles (J), primiparous (Fp) and mutiparous (Fm) females, by fishing area and by year.

Year	Estuary			Sept-Iles			Anticosti			Esquiman		
	J	Fp	Fm	J	Fp	Fm	J	Fp	Fm	J	Fp	Fm
1990	36	48	67	159	959	853	144	1535	610	15	1157	238
1991	0	57	138	360	773	1505	87	838	622	77	539	440
1992	2	43	85	307	556	404	414	844	408	57	554	106
1993	7	78	14	61	1030	234	17	580	92	24	234	124
1994	1	130	33	156	1600	318	14	802	118	98	626	89
1995	12	14	5	188	1495	211	502	2408	273	30	1182	185
1996	1	132	94	165	2010	655	1279	4049	721	733	880	327
1997	0	110	22	30	2293	535	609	2378	226	57	2063	727
1998	7	29	20	749	3483	711	286	2171	392	652	1567	241
1999	3	158	47	6	2705	405	26	2067	492	136	1283	562
2000	1	181	76	280	4542	785	707	3457	551	736	1611	525
2001	1			81			20			300		
2002	1			88			443			19		
2003	176			167			30			41		
2004	0			9			47			17		
2005	0			93			148			374		
2006	0			56			201			84		
2007	3			530			228			383		
2008	2			161			103			41		
2009	3	27	105	11	2021	2288	235	2114	1143	64	1700	673
2010	0	60	69	41	3391	1879	40	1835	1417	146	1076	1392
2011	0	118	113	14	2057	1581	83	1708	712	565	2515	887
2012	2	257	48	202	2609	1021	27	1996	561	81	1590	491
2008+	134			161								
2009+	702	194	215	11	2021	2288						
2010+	9	321	146	41	3398	1883						
2011+	102	237	196	14	2043	1570						
2012+	65	442	144	205	2599	1018						

+: From 2008, the sampling was increased with the addition of strata in shallow waters (37 to 183 m) in the Estuary.

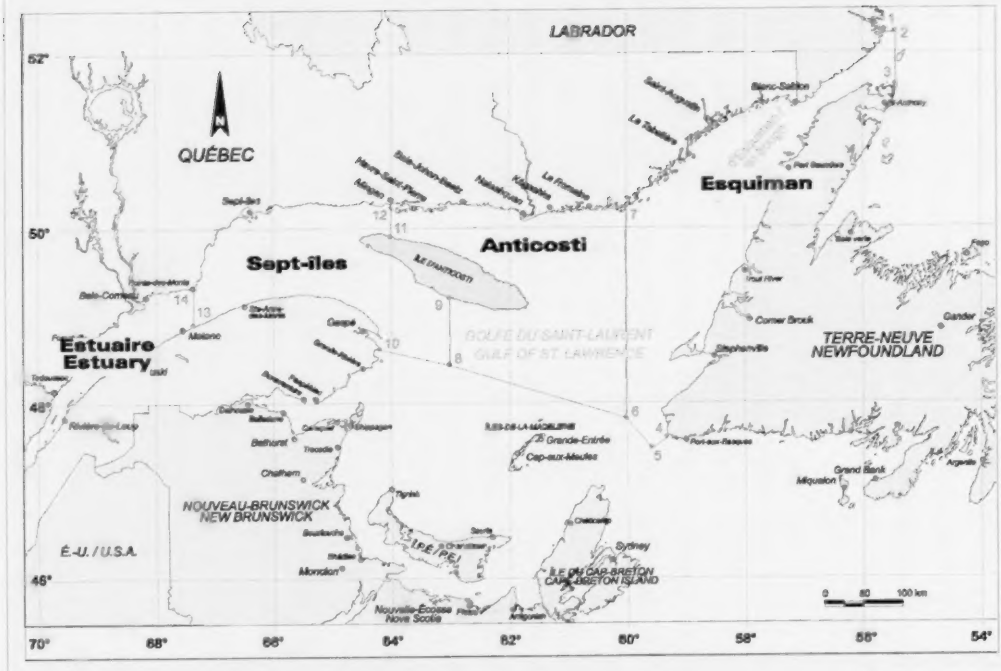

Figure 1. Shrimp fishing areas (SFA) in the Northern Gulf of St. Lawrence: Estuary, SFA 12; Sept-Iles, SFA 10; Anticosti, SFA 9; Esquiman, SFA 8.

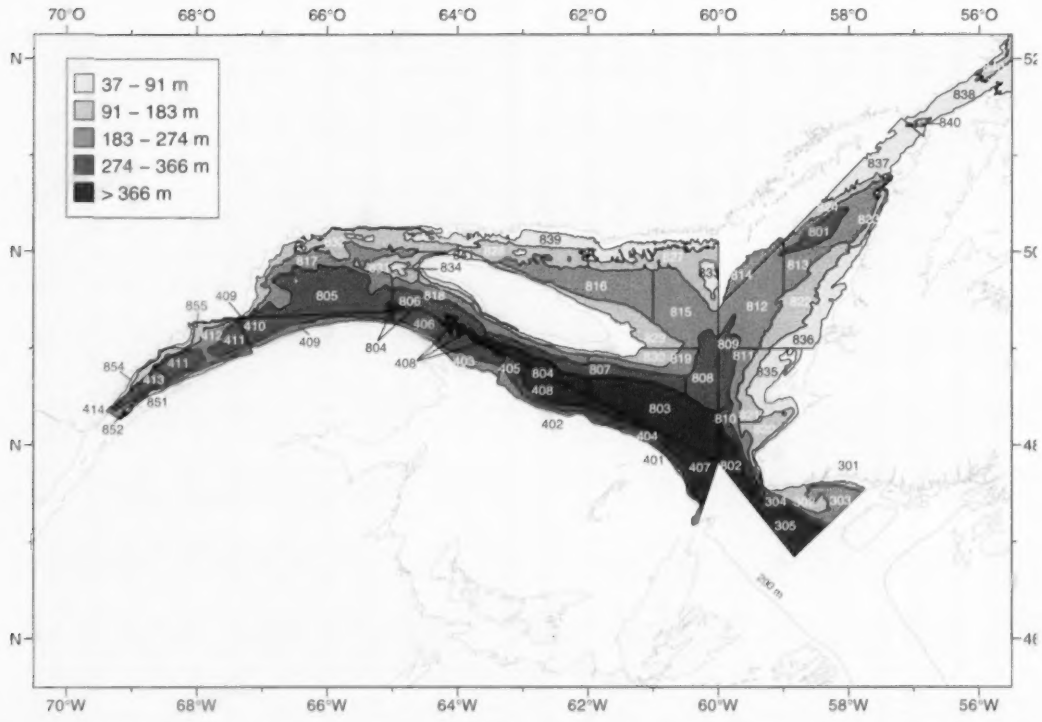

Figure 2. Stratification used for the allocation of fishing stations of the survey in the northern Gulf of St. Lawrence. The strata 851, 852, 854 and 855 were added in 2008.

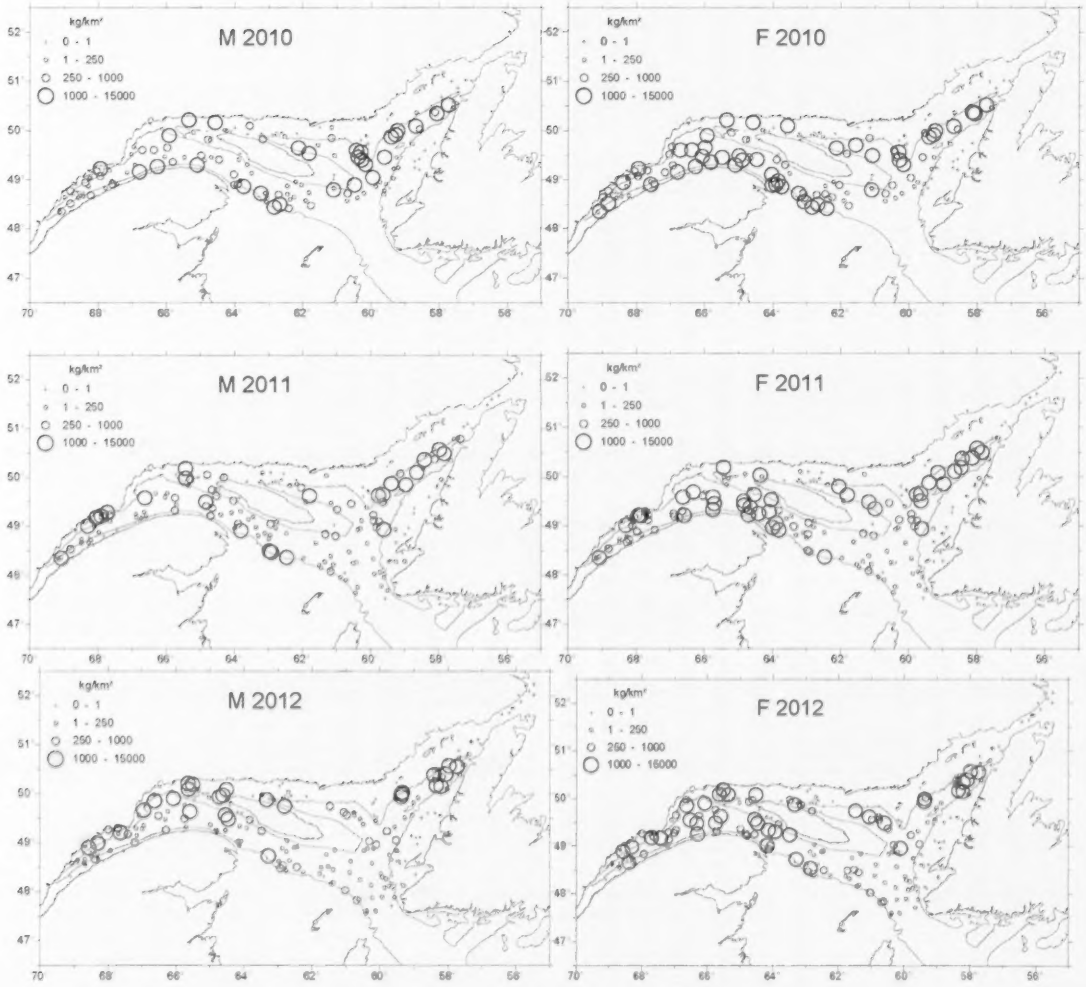

Figure 3. Distribution of shrimp catches in 2010, 2011 and 2012.

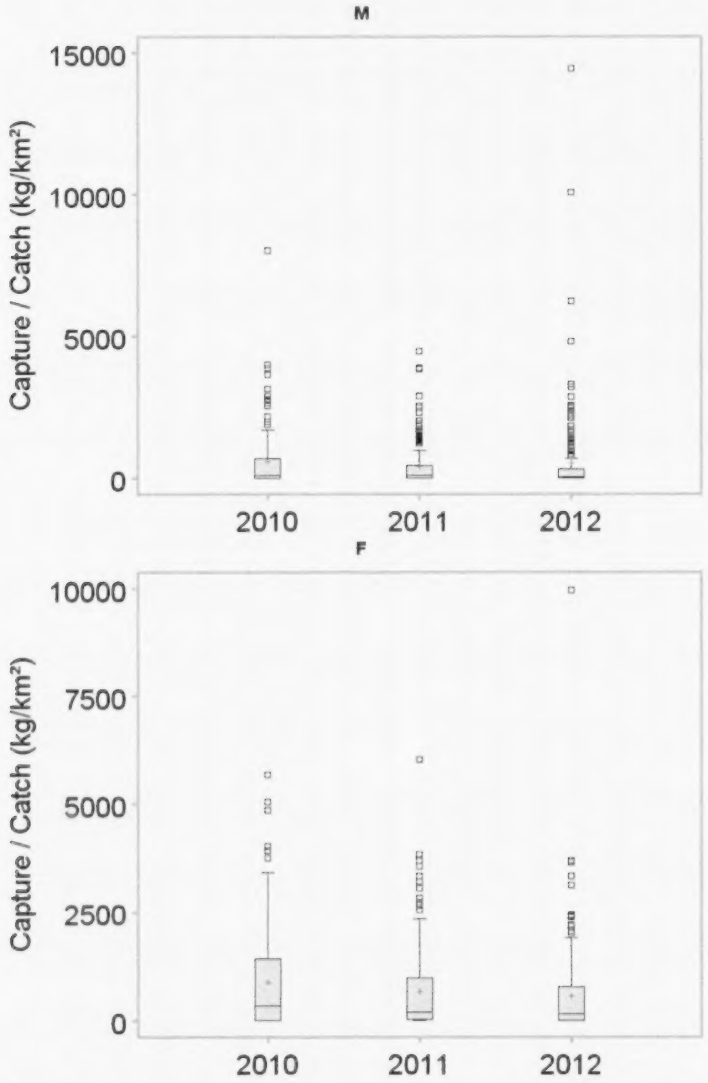

Figure 4. Boxplot of catches (kg/km²) obtained from the surveys conducted from 2010 to 2012. Rectangle: from the first to the third quartile with the median. Whiskers: 1.5 times the interquartile interval that was reported to the closest lower data point. Cross: all data points higher than the whiskers.

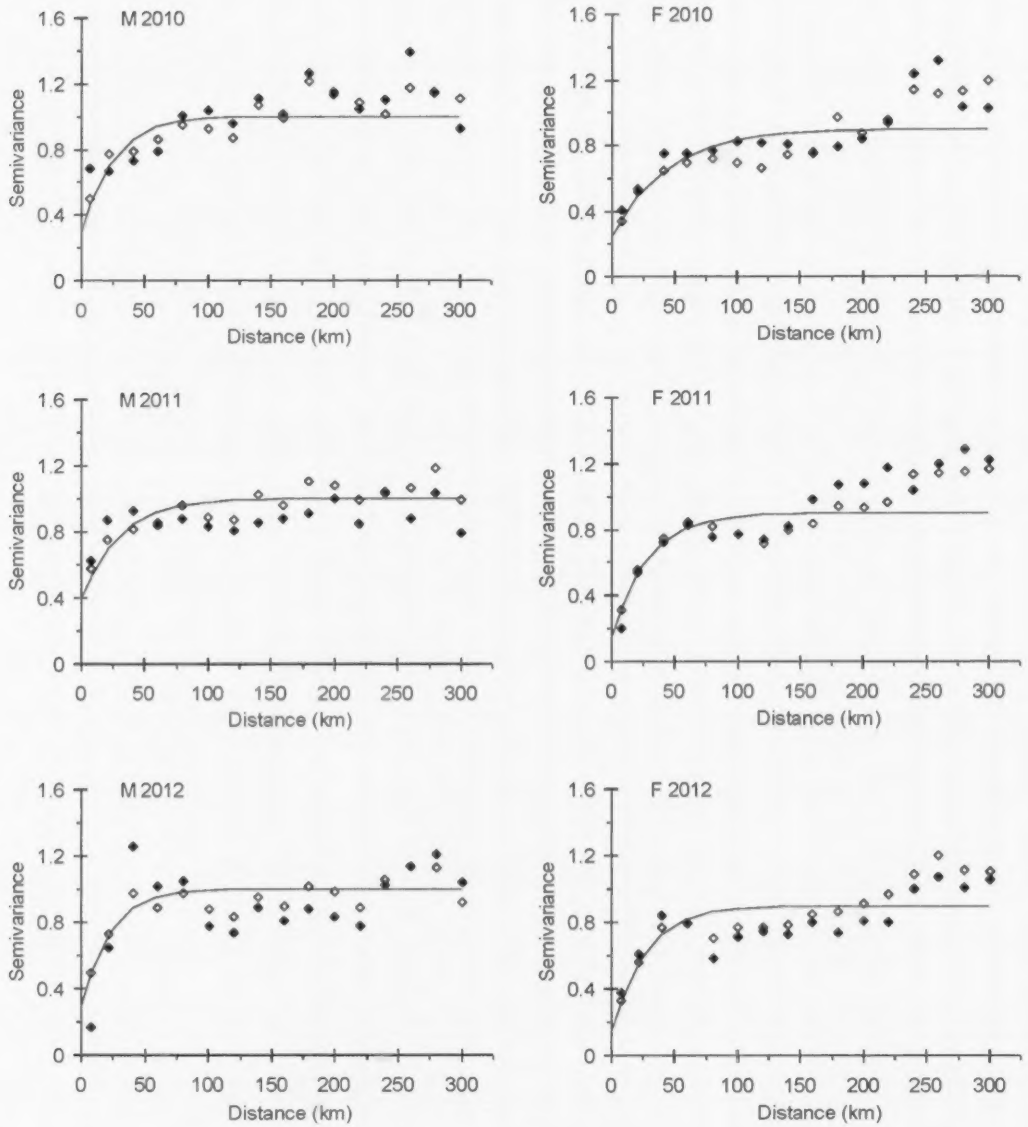

Figure 5. Isotropic variograms of the biomasses (kg/km²) for the years 2010 to 2012. Filled circles: current year. Open circles: mean over three years. Curve: variogram adjusted on the 3 year mean.

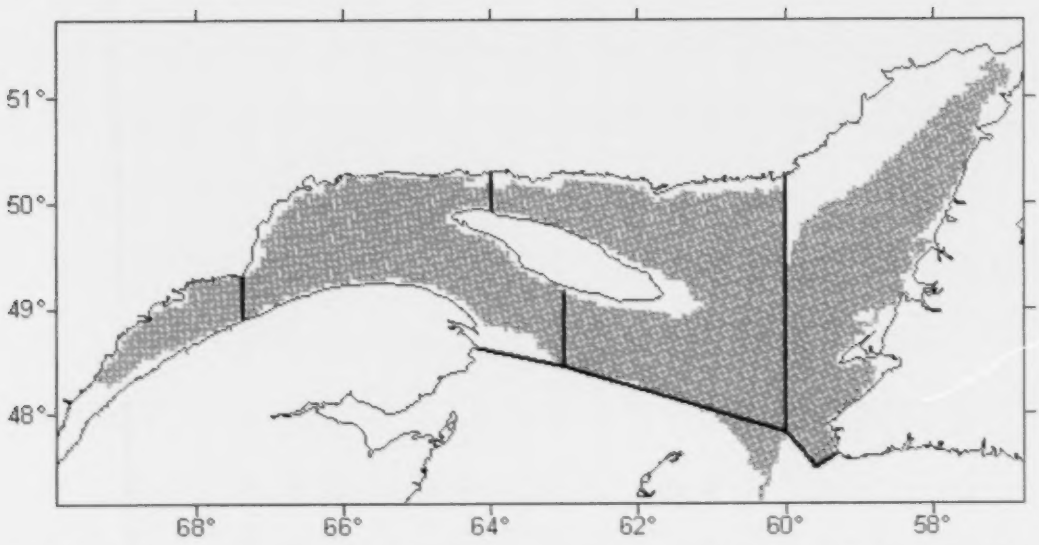

Figure 6. Studied area for the kriging of the shrimp biomass in the northern Gulf of St. Lawrence. The limits of the fishing areas are indicated as well.

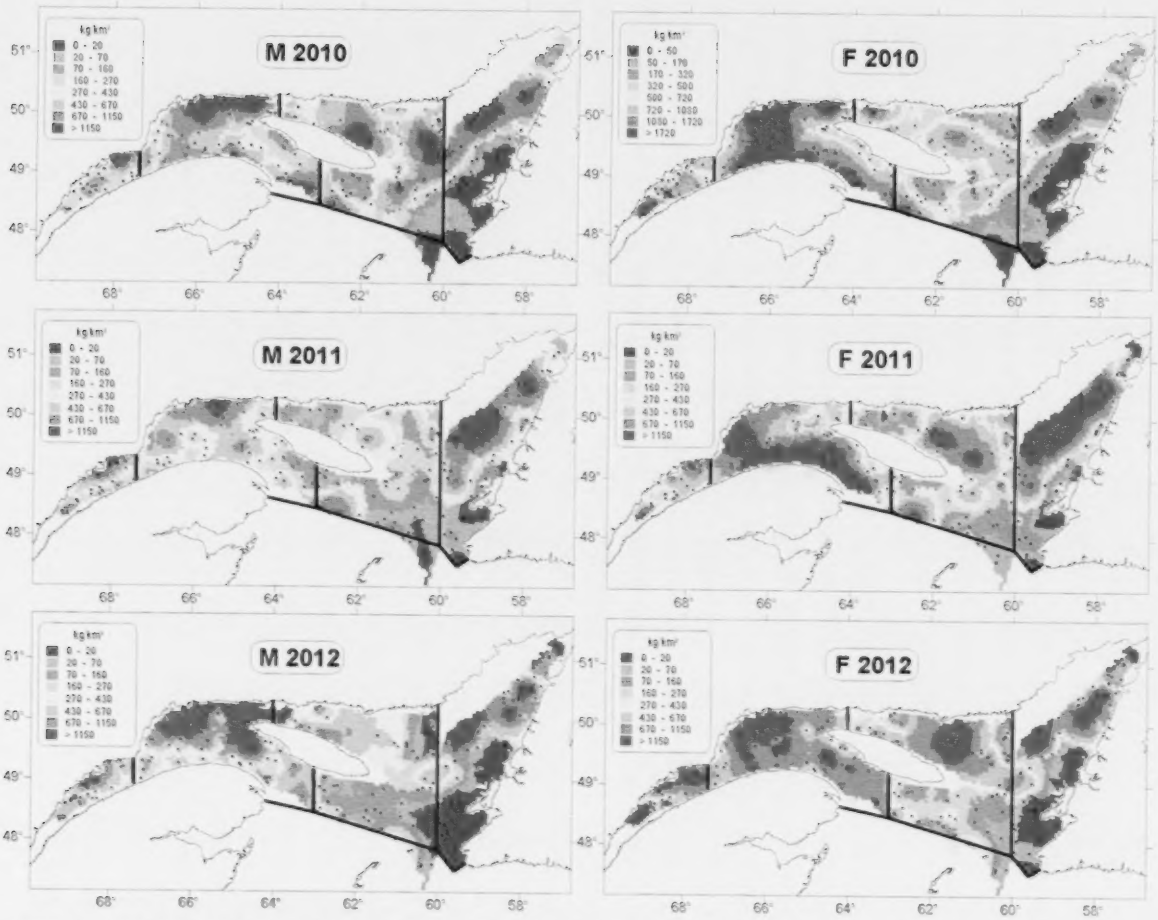

Figure 7. Distribution of the biomass (kg/km²) obtained by kriging by block of 25 km² from 2010 to 2012 for males (M) and females (F).

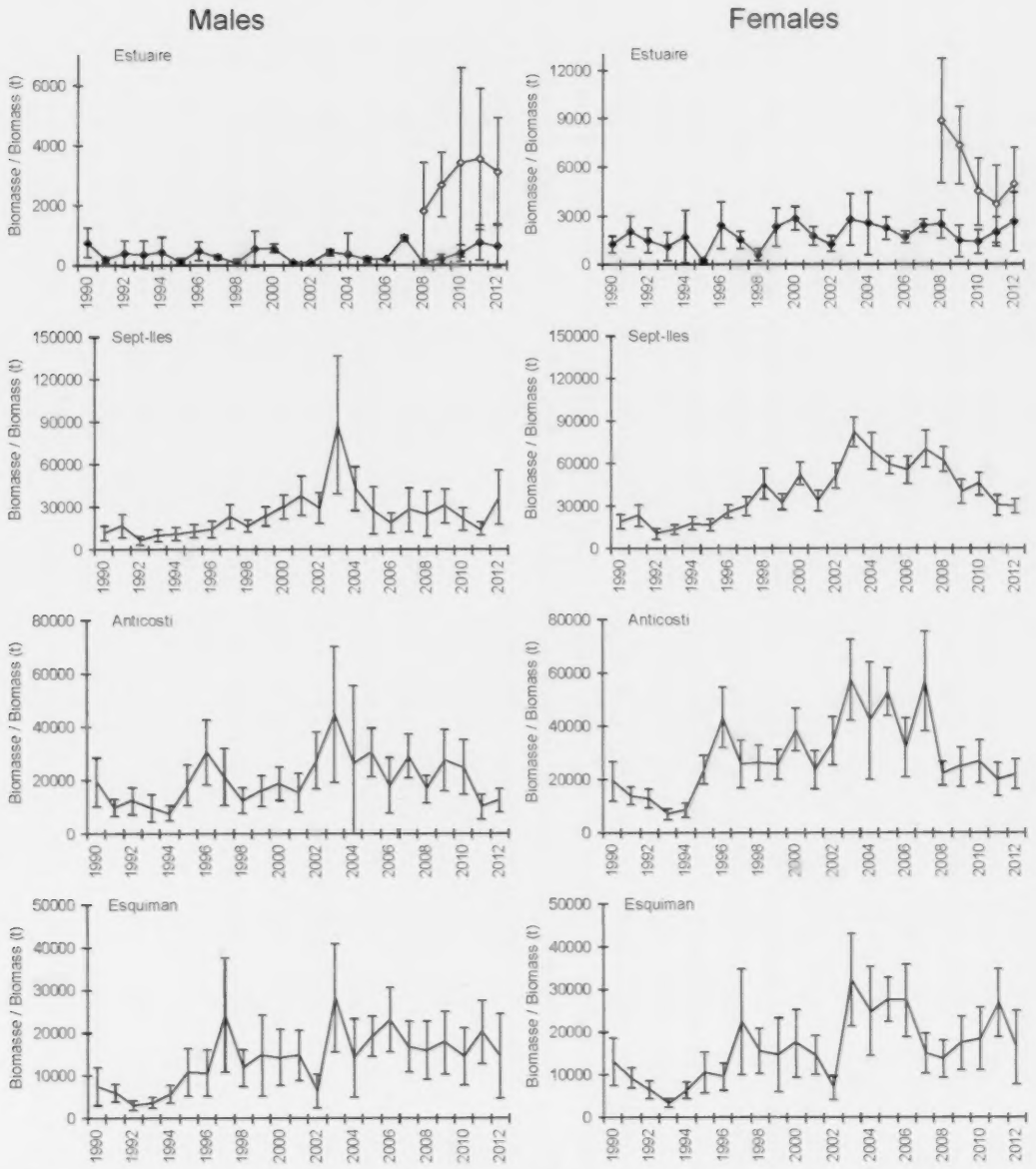

Figure 8. Biomass (in ton) by fishing area and by year, for males and females. The open circles from 2008 to 2012 show the results obtained when adding strata in shallow waters (37-183 m) of the estuary. Error bars indicate the 95% confidence interval.

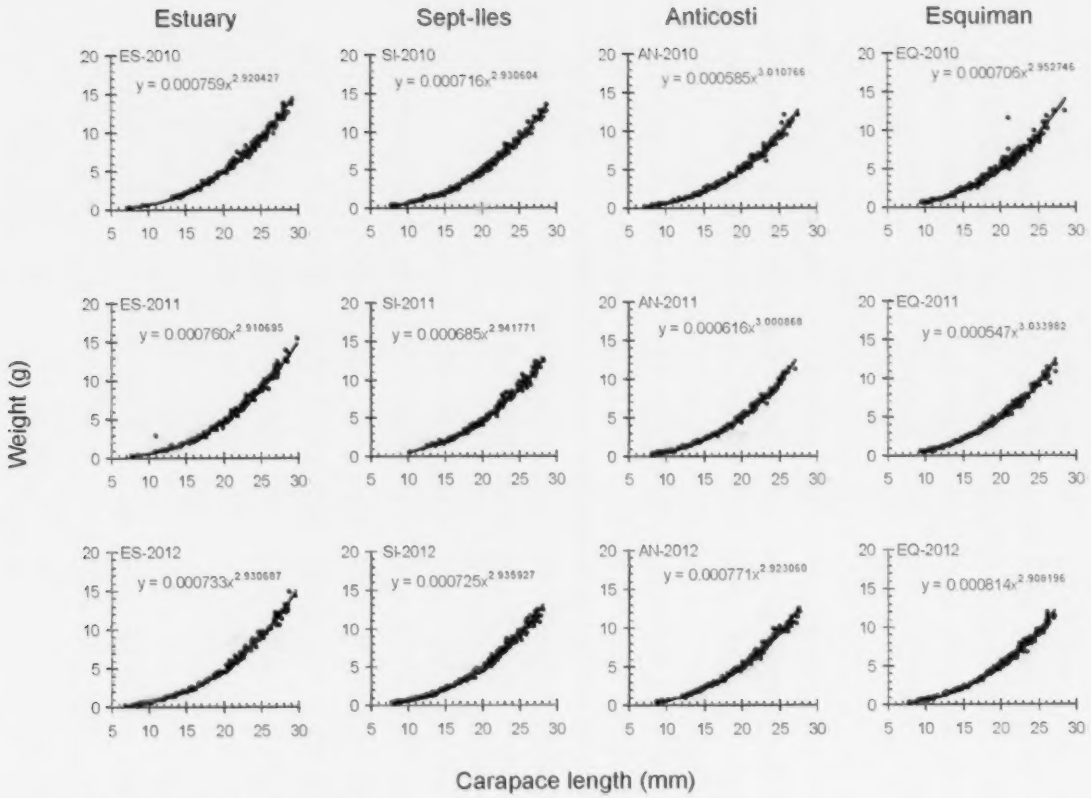

Figure 9. Weight-length relationships by fishing area from 2010 to 2012.

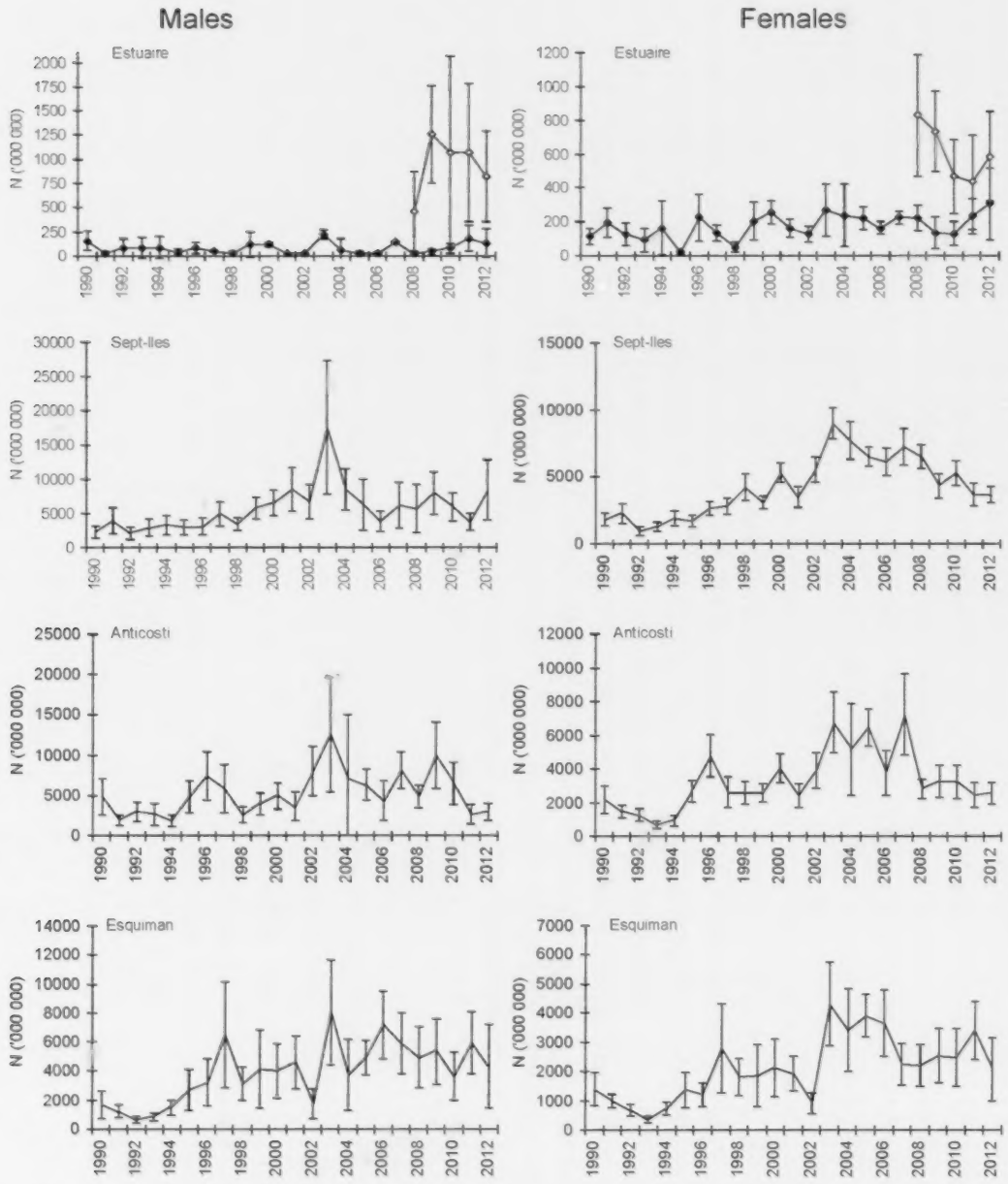

Figure 10. Abundance (in million) by fishing area and by year, for males and females. The open circles in 2010, 2011 and 2012 show the results obtained when adding strata in shallow waters (37-183 m) of the estuary. Error bars indicate the 95% confidence interval.

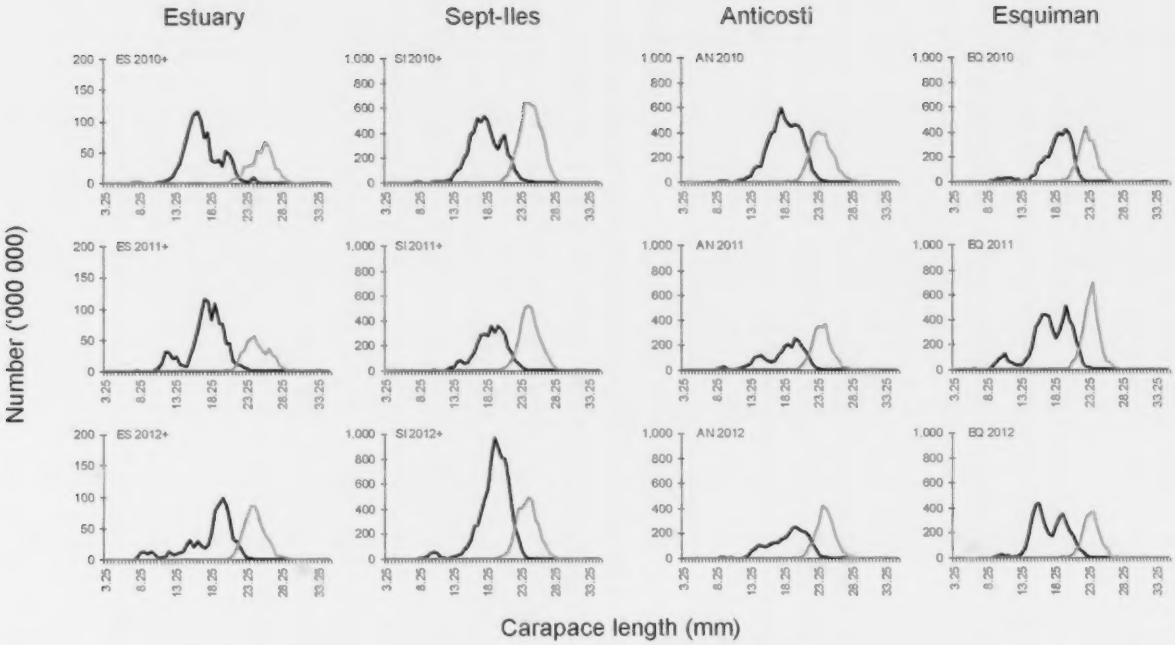

Figure 11. Abundance (in million) by carapace length class (classes of 0.5 mm) by fishing area from 2010 to 2012 for males (in blue) and females (in red). The + placed beside the year shows the results obtained when adding strata in shallow waters (37-183 m) of the estuary.

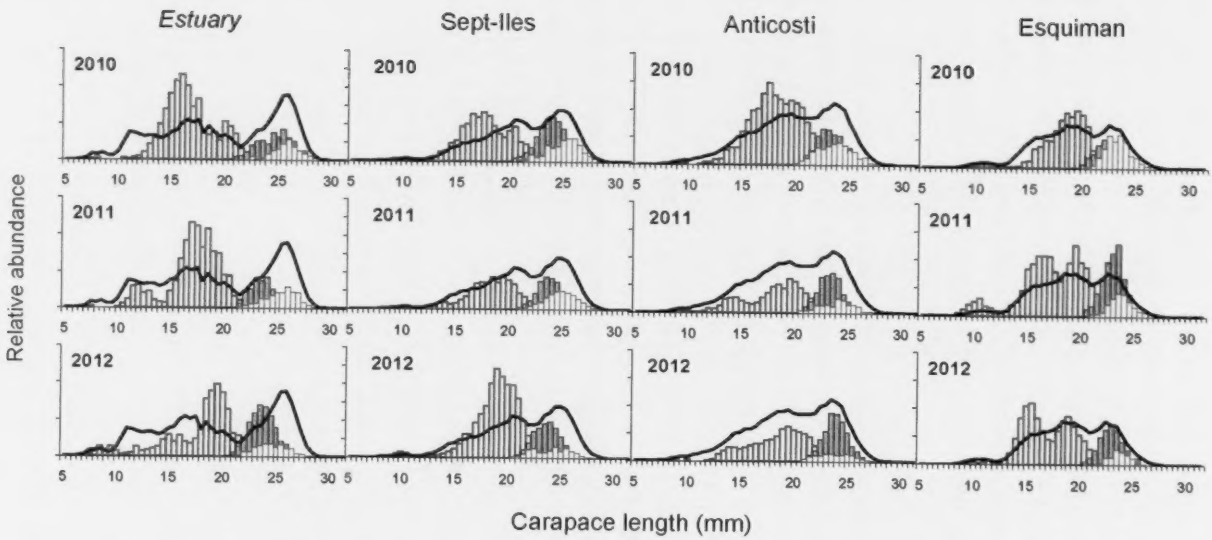

Figure 12. Relative abundance by carapace length class (classes of 0.5 mm) by fishing area from 2010 to 2012 for males (in blue), primiparous females (in gray) and multiparous females (in yellow). The straight line indicates the 1990-2010 mean. The length frequencies for the Estuary area correspond to the expanded coverage and the mean was estimated from 2008 to 2011.